BULLETIN 226 JULY 1943

Georgia Experiment Station

EXPERIMENT, GEORGIA

of the

UNIVERSITY SYSTEM OF GEORGIA

In cooperation with

BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING, UNITED STATES DEPARTMENT OF AGRICULTURE

The Effect Of Nitrogen Fertilization On Cold Injury Of Peach Trees

By

B. B. HIGGINS

Georgia Agricultural Experiment Station

and

G. P. WALTON AND J. J. SKINNER

United States Department of Agriculture

Bulletins of this Station are sent free to residents of Georgia.

H. P. STUCKEY, *Director*

EXPERIMENT, GEORGIA

The Effect Of Nitrogen Fertilization On Cold Injury Of Peach Trees

B. B. Higgins, G. P. Walton,[1] and J. J. Skinner[2]

Comparatively few studies of winter injury or cold injury of fruit trees have been carried out in the South. While the effect of cold on flower buds is evident, cold injury on the trunks of fruit trees has generally been attributed to other causes, and only in recent years has the importance of this injury been recognized by southern orchardists.

Extensive studies[3] of winter injury have been made in the northern and northeastern states, especially in New York and Michigan, where several types of cold injury have been noted: injury to flower buds, killing of twigs, sun scald type of injury to trunks and larger branches, crotch injury, crown injury, and root killing, killing of young wood (producing frost rings and "black heart"), killing of cambium, bark splitting, and several other minor or less common types of injury have been mentioned. In these more northern regions the injury has usually been associated with immaturity of the wood, due to cultural practices that kept the trees in active growth until late in the season, extremely warm weather and abundant rainfall during the fall following a dry summer season, loss of leaves during the summer and early fall, exhaustion of the reserves in trees by excessive fruit production, etc.

In the peach-growing sections of Georgia, and elsewhere within the cotton belt, environmental conditions are quite different from those found farther north. Here the growing season is long, the peach crop is usually harvested during July, and there is ample time before leaf-fall for peach trees to replace their depleted store of carbohydrates and other nutrients. Rainfall is usually low during September and October, effectively stopping active growth even in non-bearing trees, and the onset of cold weather through October and November is so gradual that the wood is usually well hardened. Occasionally rust or other leaf diseases may defoliate the trees early enough to prevent normal maturity of the wood, but this is not common. Consequently cases of cold injury to peach trees during early winter appear to be rather rare.

On the other hand, our winters are generally mild, with occasional periods of freezing weather interspersed with extensive periods of warm days. Usually peach blossom buds are swollen, often showing pink, by the middle of February, and temperatures

1. Bureau of Agricultural Chemistry and Engineering, United States Department of Agriculture.

2. Bureau of Plant Industry, United States Department of Agriculture.

3. The very voluminous literature related to cold injury and low temperature relations of plants has recently been reviewed and summarized in several publications, those publications especially related to cold injury are reviewed in a recent book: Levitt, J. Frost Killing and Hardiness in Plants. 211 pp. Burgess Publishing Company, Minneapolis, Minn. 1941. For this reason no review of the literature will be given here.

of 20° Fahrenheit or lower, coming after the trees have reached this condition, usually cause considerable injury to both flower buds and the cambial area of the trunks.

Usually injury to the trunks is of the sun-scald type and confined to the south, southwest, or the southeast side of the trunk, but in case of a severe freeze the trunks may be entirely girdled with the greatest amount of killing on the north or windward side. The latter type of injury was severe in 1933 following a sudden drop in temperature of 49° Fahrenheit from a maximum of 55° on February 8 to a minimum of 6° the following morning. At this time flower buds of the Elberta were showing pink, and 75 to 95 per cent were killed throughout Georgia. Twigs and even large branches were killed, and severe killing of the trunk cambium occurred in most orchards.

We have few authentic records for Georgia of cold injury on roots of peach trees, and few of injury to trunks below the soil line. Even following the severe freeze of 1933, most of the injured trees sent up vigorous sprouts from the crown during the spring. Neither have we any records of frost ring or black-heart type of injury due to killing of wood rather than cambium, so frequently reported in more northern regions. Most of our cold injury occurs during February or early March after the cambium has become more or less active and this region is more subject to injury than either the sapwood or the bark.

In more northern latitudes most winter injury is thought to be associated with immaturity of the wood and most commonly occurs in early winter. Therefore, cultural practices that minimize late growth are generally recommended. Fruit growers are usually urged to avoid late cultivation and excessive use of nitrogenous fertilizers, especially late in the growing season.

Observations over a number of years indicate that in Georgia vigorously growing peach trees are least subject to cold injury. Following the severe winter of 1927-1928, observations in a Pike County orchard, used for fertilizer tests, indicated that in blocks receiving the highest applications of nitrogen the trees showed least cold injury. In order to obtain more exact data upon this point, a fertilizer test, with rate and time of nitrogen fertilization as the principal variable, was started in 1929.

EXPERIMENTAL METHODS

PLANTING AND FERTILIZER TREATMENTS. The area selected for the experimental orchard was on the Experiment Station farm near Griffin and consisted of approximately 3½ acres located on top of a narrow plateau with about equal areas of gentle slope facing north and south respectively. The soil was fairly uniform Cecil sandy clay loam (old classification) of medium fertility. The soil, exposure, and other environmental features were quite typical of commercial orchards of the region except that it did not include any low flat areas that might complicate our results.

The peach trees, June buds of the Elberta variety, were obtained from a local nursery and set January 8, 1929. They were spaced 17½ feet apart each way, being set somewhat closer than in commercial orchards because replacement of dead trees was not intended and removal of the trees after obtaining data on cold injury was planned. No fertilizer was applied during the first season. The second winter the orchard was divided into 21 blocks of 16 trees each, for variations in nitrogen fertilization, and 3 blocks of 12 trees each, to be used for preliminary tests with higher rates of potash fertilization, with a single row of border trees on three sides of the orchard. This gave three series of seven blocks each completely randomized for the nitrogen tests. The blocks in each series received fertilizer with analysis as follows:

Block 1	No fertilizer, check		
" 2	0-8-6*	applied	March 1
" 3	4-8-6	"	" "
" 4	8-8-6	"	" "
" 5	4-8-6	"	" "
	4-0-0	"	June 1
" 6	12-8-6	"	March 1
" 7	4-8-6	"	" "
	4-0-0	"	June 1
	4-0-0	"	August 1

*Percentage nitrogen-phosphoric acid-potash.

The 3 blocks of 12 trees each used for preliminary tests with potash received fertilizers analyzing 4-8-10, 4-8-14, and 4-8-18 respectively, all applied March 1.

In the basal fertilizer the nitrogen was derived 50 per cent from sodium nitrate, 33.3 per cent from ammonium phosphate, and 16.7 per cent from cotton seed meal. With the split applications, Blocks 5 and 7, all the summer applications consisted of sodium nitrate so that approximately 75 per cent and 84 per cent, respectively, of the nitrogen for these two blocks was supplied in the form of sodium nitrate.

The rate of application varied with age of the trees: 3 pounds per tree in 1930, 4 pounds in 1931, 5 pounds in 1932 and again in 1933; in 1934 and each year thereafter, 6 pounds per tree.

In addition to the fertilizer application, a summer cover crop (Laredo soybeans) was sown in the central series on August 1 each year until 1936, when the trees had almost completely shaded the soil, the purpose being rapid removal of moisture to prevent late growth of the trees.

RELATION OF SUNLIGHT TO COLD INJURY. The trees comprising the outside or border rows on the south, east, and north sides of the orchard, 76 in number, were used in a preliminary test of the effect on cold injury of coating the tree trunk and lower portions

of larger branches with either (1) an efficient light- and heat-reflecting whitewash, or (2) a dull blackwash possessing high light- and heat-absorbing power.

Except for slight changes in the amounts of water used the whitewash was prepared by "Formula 4" in National Lime Association's Bulletin No. 204C, entitled, "Whitewash and Cold Water Paints."[1] It was a lime-casein-trisodium phosphate cold water paint to which formaldehyde was added just before applying. The blackwash was similar except that the lime was replaced by a good grade of finely pulverized lampblack. Ten pounds of hydrated lime was used for 3 gallons of whitewash and 5 pounds of lampblack for 4¼ gallons of blackwash.

The whitewash was applied to alternate trees, 38 in number, in the border rows, and the other 38 were painted with the blackwash. Applications were made twice each winter.

RECORDS OF COLD INJURY. Counts of injured flower buds were made as soon as possible after a freeze occurred during February and March. Injuries to the trunks and large branches were examined during May each year, noting the location, type, and extent in each case. In 1932 bud counts were made on only one series, but in subsequent years at least 300 buds were examined from each block and the average for the three series obtained. In 1935 and again in 1938 there was little injury to flower buds and counts were not made. Exact counts were not obtained in 1940 and 1941 and are not recorded in Table 6.

GROWTH AND PRODUCTION RECORDS. Records of tree growth, as affected by the fertilizers, the relation of fertilizers to number, size, coloring, and other qualities of the fruits, were kept by the Experiment Station horticulturists and are being reported along with results from fertilizer tests on other soil types of Georgia. These factors will not be considered in the present publication.

TWIG SAMPLING AND ANALYSIS. In order to ascertain the influence of the variations in nitrogen content of the fertilizer upon the chemical composition of the new wood and any possible correlation of this composition with susceptibility to cold injury, twig samples were collected from each block on December 15 and again on February 15 of the winters 1930-31, 1931-32, 1932-33, and 1933-34 for analysis to determine total dry matter, ash, nitrogen, and reducing and non-reducing sugars. In the 1933-34 samples, determinations of glycosidic sugar were also made.

At the first sampling ten twigs ten inches long of the current season growth were cut at random from all sections of each tree. The twigs from each block were tied into a bundle, carried to the laboratory, and placed in cold (37° C.) storage. Each bundle was then removed from storage, a portion of the twigs cut into one-fourth inch pieces, weighed, and placed in quart fruit jars with 500 ml. of 95 per cent ethyl alcohol, boiled for a few minutes, and the

1. See also: Fink, G. J. Investigation of whitewashes and aqueous lime paints, formula No. 29. Jour. Indust. and Engineering Chemistry 14 (6): 503-511. June 1922.

jar then sealed. The remainder of the sample was weighed and wrapped in paper. Both wet and dry samples were then packed and shipped by express to Washington, where the analyses were made. The dry samples were there immediately oven-dried for comparison, in certain determinations, with the wet material. The dry material was found unsatisfactory for analysis and in subsequent samplings only six twigs were cut from each tree and only the tip four inches of each twig was used in preparing the sample. The entire sample was prepared, weighed, and preserved in 500 ml. of alcohol plus 5 grams of very finely pulverized precipitate of $CaCO_3$, then boiled and sealed as described above. In every case the twig samples were collected during the early morning and preservation in alcohol was completed the same day.

As received in the laboratory, the samples comprised the partially extracted cut-up twigs covered by the alcoholic solution which filled the jars about two-thirds full. The dry matter in the extracted twigs amounted to around 60 to 80 grams; and the somewhat less than 500 ml. of alcoholic extract contained 2 to 3 per cent of total solids in solution. A noticeable quantity of suspended fine material, largely made up of a gray, wax-like substance, was present. Where calcium carbonate had been added to the sample, this was also included with the fine material.

The solid twig material was separated from the alcoholic extract by filtration of the alcoholic solution. Drying, of the solid twig material remaining in the jar, was accomplished by supporting the jar on its side over a steam radiator over night, with the material spread over the lower side of the jar. This was found to be effective and convenient for a large number of samples.

The dry twig material was transferred to a piece of smooth-finished paper. The fruit jar was rinsed with about 50 ml. of 95 per cent alcohol and was warmed to dissolve any dried, gummy material. The air-dry, gray waxy sediment filtered out of the alcohol extract of the twigs, was removed from the filter paper with a thin spatula, and added to the rest of the solid twig material. The filter paper was then replaced in the funnel, moistened with alcohol, and the wash-alcohol in the fruit jar was passed through it, using a small, clean bristle brush to remove any adhering material. Finally, the alcoholic washings were added to the extract contained in a 1-liter volumetric flask, and made up to the liter mark. This was designated as Solution A.

Any solid material on the filter paper was added to the rest of the twig material, and this combined solid material was returned to the fruit jar after the jar had been dried. This combined solid twig material (designated S) was dried at a temperature of 60° to 70° C. for about 48 hours to eliminate alcohol, then stored open to the air at room temperature for a week or ten days to bring it to an air-dried condition, determined by periodic weighing. The air-dry twig material was then transferred to an air-tight sample jar. The weight obtained (S) is the total air-dry weight of the solid portion of the twigs and any added calcium carbonate. This

solid material was ground to pass a 40-mesh sieve, mixed and preserved in the sample jar for analysis.

The liter of alcoholic extract, Solution A, was transferred to the cleaned fruit jar for storage and hermetically sealed.

The original twig sample has now been brought into condition suitable and convenient for analysis. Its total dry matter is represented by the total dry matter in the solid material (S) plus the total solids in the liter of extract (A) minus the added calcium carbonate. Hence, the total dry matter, or any other constituent, found in a given aliquot of the extract (A) taken along with the same fractional part of the weight of the air-dry solid material (S), would represent the quantity of that constituent in the same fractional part of the original twig sample. It is, therefore, feasible to ascertain the amount of a given constituent in the original twigs by making only a single determination of that constituent on one charge of material comprising an aliquot of the alcoholic extract (A) and a like fraction of the weight of the air-dry solid material (S). For example, if an aliquot of 50 ml. of the alcoholic extract is taken for a determination, the charge is completed by adding thereto a quantity of the ground solid material equal to one-twentieth of the total air-dry weight (S).

With slight variations to fit the material under examination, the method of analysis employed after the sample had been prepared as above described, are in general those of the Association of Official Agricultural Chemists, as described in the Book of Methods, Eds. 3 & 4 (1930 and 1935).

RESULTS

ANALYTICAL. The results of the determinations for total dry matter, ash, nitrogen, reducing sugars, and non-reducing sugars, as well as total sugars, as found in the twigs in the years 1930-31, 1931-32, 1932-33, and 1933-34 from the plots receiving no fertilizer, no nitrogen and the varying rates and time of applying nitrogen are given in Tables 1 to 4.

In these four tables, the figures showing the percentage composition of the twigs are, in each case, the average of three samples analyzed, each sample having been taken from a different orchard plot receiving the same fertilizer application. Actually 21 twig samples and a "blank" on the alcohol, $CaCO_3$, etc., were analyzed for each December and each February sampling date, to yield the data contained in Tables 1 to 4, which give the results obtained for varying applications of nitrogen.

TOTAL DRY MATTER. In general, the dry matter of the peach twigs is higher in December than in February, in the three winter seasons from 1930-33 as shown in Tables 1, 2, and 3. This relation is reversed in the winter of 1933-34,[1] as shown in Table 4, but the

1. This was due, doubtless, to the almost continuous low temperatures which had prevented growth activity in peach trees.

TABLE I

EFFECT OF NITROGEN FERTILIZER ON COMPOSITION OF PEACH TREE TWIGS. FERTILIZER APPLICATION IN 1930 EQUALS 3 POUNDS PER TREE. COMPOSITION STATED IN PERCENTAGE OF DRY MATTER.

CONSTITUENTS	DATE 1930-31	NO FERTILIZER	NITROGEN PERCENTAGE OF FERTILIZER WITH 8 PER CENT PHOSPHORIC ACID AND 6 PER CENT POTASH[1]						AVERAGE
			0	4	8	12	4+4[2]	4+4+4[3]	
		per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Total dry matter in twigs as cut	Dec.	46.92	44.86	47.01	46.93	46.32	46.89	46.62	46.51
	Feb.	44.64	43.28	42.87	43.41	43.84	43.27	43.48	43.54
Ash	Dec.	4.20	4.30	3.90	4.20	3.70	3.80	3.80	3.97
	Feb.	4.30	4.60	4.50	4.40	4.30	4.70	4.50	4.61
Nitrogen	Dec.	1.17	1.41	1.41	1.52	1.46	1.45	1.51	1.42
	Feb.	1.47	1.77	1.82	1.87	1.79	1.52	1.93	1.74
Reducing sugars (invert sugar)	Dec.	2.81	2.85	2.72	2.52	2.64	2.68	2.61	2.69
	Feb.	2.97	2.90	2.79	2.63	2.73	3.35	2.72	2.87
Non-reducing sugars (sucrose)	Dec.	3.43	3.35	3.42	3.37	3.70	3.36	3.58	3.46
	Feb.	2.90	2.68	2.98	2.96	3.14	2.30	3.02	2.85
Total sugars	Dec.	6.24	6.20	6.14	5.89	6.34	6.04	6.19	6.15
	Feb.	5.87	5.58	5.77	5.59	5.87	5.65	5.74	5.72

[1]Fertilizer applied March 1, 1930.
[2]One-half of nitrogen applied June 1.
[3]One-third of nitrogen applied June 1 and one-third applied August 1.

TABLE II

EFFECT OF NITROGEN FERTILIZER ON COMPOSITION OF PEACH TREE TWIGS. FERTILIZER APPLICATION IN 1931 EQUALS 5 POUNDS PER TREE. COMPOSITION STATED IN PERCENTAGE OF DRY MATTER.

CONSTITUENTS	WINTER 1931–32	NO FERTILIZER	NITROGEN PERCENTAGE OF FERTILIZER WITH 8 PER CENT PHOSPHORIC ACID AND 6 PER CENT POTASH[1]						AVERAGE
			0	4	8	12	4+4[2]	4+4+4[3]	
		per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Total dry matter in twigs as cut	Dec.	45.69	45.67	45.67	45.72	45.23	45.39	45.38	45.54
	Feb.	44.90	44.96	45.97	44.84	45.01	44.89	45.31	45.13
Ash	Dec.	5.48	4.74	4.53	4.14	4.00	4.72	4.57	4.60
	Feb.	5.80	4.85	4.59	4.34	4.30	4.94	4.53	4.76
Nitrogen	Dec.	1.54	1.72	1.76	1.94	1.66	1.85	2.01	1.78
	Feb.	1.67	1.79	1.86	2.01	2.01	1.92	2.15	1.91
Reducing sugars (invert sugar)	Dec.	2.10	1.96	1.91	1.94	1.96	2.06	1.91	1.98
	Feb.	2.36	1.60	2.29	2.19	2.29	2.15	2.11	2.13
Non-reducing sugars (sucrose)	Dec.	2.84	3.00	3.05	2.97	3.10	2.95	3.19	3.01
	Feb.	3.01	2.84	2.98	2.92	2.86	2.30	2.68	2.80
Total sugars	Dec.	4.92	4.96	4.96	4.91	5.03	5.01	5.11	4.99
	Feb.	5.35	5.11	5.28	5.11	5.15	5.14	5.12	5.18

[1]Fertilizer applied March 1, 1931.
[2]One-half of nitrogen applied June 1.
[3]One-third of nitrogen applied June 1, and one-third applied August 1.

TABLE III

EFFECT OF NITROGEN FERTILIZER ON COMPOSITION OF PEACH TREE TWIGS. FERTILIZER APPLICATION IN 1932 EQUALS 5 POUNDS PER TREE. COMPOSITION STATED IN PERCENTAGE OF DRY MATTER.

CONSTITUENTS	WINTER 1932-33	NO FERTILIZER	NITROGEN PERCENTAGE OF FERTILIZER WITH 8 PER CENT PHOSPHORIC ACID AND 6 PER CENT POTASH[1]						AVERAGE
			0	4	8	12	4+4[2]	4+4+4[3]	
		per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Total dry matter in twigs as cut	Dec.	45.45	42.61	45.55	45.06	45.43	45.81	45.47	45.05
	Feb.	43.26	42.87	42.59	42.19	42.11	42.40	42.20	42.51
Ash	Dec.	5.09	4.67	4.60	4.71	4.14	4.43	4.60	4.61
	Feb.	5.44	4.71	4.40	4.37	4.23	4.71	4.52	4.63
Nitrogen	Dec.	1.45	1.76	1.73	1.96	1.95	1.94	1.89	1.81
	Feb.	1.66	1.77	1.86	2.11	2.15	1.91	2.21	1.95
Reducing sugars (invert sugar)	Dec.	2.66	2.45	2.43	2.28	2.33	2.34	2.39	2.41
	Feb.	2.42	2.24	2.23	2.00	1.95	2.11	2.00	2.14
Non-reducing sugars (sucrose)	Dec.	3.83	3.84	4.02	3.91	4.08	4.16	4.13	4.00
	Feb.	2.87	2.88	2.78	2.88	2.99	2.77	2.83	2.86
Total sugars	Dec.	6.49	6.30	6.45	6.19	6.41	6.50	6.52	6.41
	Feb.	5.29	5.11	5.01	4.88	4.94	4.88	4.83	4.99

[1]Fertilizer applied March 1, 1932.
[2]One-half of nitrogen applied June 1.
[3]One-third of nitrogen applied June 1 and one-third applied August 1.

TABLE IV

EFFECT OF NITROGEN FERTILIZER ON COMPOSITION OF PEACH TREE TWIGS. FERTILIZER APPLICATION IN 1933 EQUALS 6 POUNDS PER TREE. COMPOSITION STATED IN PERCENTAGE OF DRY MATTER.

Constituents		Winter 1933–34	No fertilizer	Nitrogen percentage of fertilizer with 8 per cent phosphoric acid and 6 per cent potash[1]						Average
				0	4	8	12	4+4[2]	4+4+4[3]	
			per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Total dry matter in twigs as cut		Dec.	43.23	43.59	43.89	44.21	44.25	44.06	44.18	43.80
		Feb.	43.60	44.01	44.28	44.72	45.42	44.57	44.25	44.41
Ash		Dec.	5.89	5.82	5.66	5.40	5.60	5.42	5.42	5.60
		Feb.	6.27	5.87	5.68	5.59	5.58	5.74	5.74	5.78
Nitrogen		Dec.	1.92	1.81	1.93	2.13	2.13	2.20	2.22	2.08
		Feb.	1.88	1.81	1.92	2.12	2.10	2.19	2.23	2.04
Reducing sugars (invert sugar)		Dec.	2.66	2.68	2.63	2.39	2.34	2.31	2.37	2.48
		Feb.	2.97	3.08	2.94	2.61	2.64	2.52	2.47	2.75
Non-reducing sugars (sucrose)		Dec.	3.86	3.72	3.70	3.74	3.91	3.87	3.87	3.81
		Feb.	4.01	3.90	3.96	4.11	4.26	4.12	4.29	4.09
Total sugars		Dec.	6.52	6.40	6.33	6.13	6.25	6.18	6.23	6.29
		Feb.	6.98	6.98	6.90	6.72	6.90	6.64	6.76	6.84
Glycosidic Sugars as Dextrose[4]	From Prunasin type	Dec.	2.53	2.45	2.56	2.84	2.92	2.95	2.89	2.72
		Feb.	2.05	1.97	2.29	2.64	2.48	2.68	2.19	2.33
	From Prunasin + Phlorazin type	Dec.	3.24	3.13	3.33	3.63	3.69	3.66	3.75	3.49
		Feb.	2.96	2.86	3.14	3.39	3.26	3.52	3.34	3.21
Total reducing sugars as dextrose[5]	Emulsin hydrolysis	Dec.	5.09	5.03	5.10	5.15	5.17	5.17	5.17	5.12
		Feb.	4.92	4.94	5.12	5.15	5.03	5.10	4.91	5.02
	Emulsin+acid hydrolysis	Dec.	9.73	9.51	9.62	9.71	9.92	9.82	9.97	9.75
		Feb.	9.90	9.81	10.00	10.09	10.18	10.14	10.08	10.03

[1]Fertilizer applied March 1, 1933.
[2]One-half of nitrogen applied June 1.
[3]One-third of nitrogen applied June 1 and one-third applied August 1.
[4]This dextrose is not included with the total sugars; it is a measure of the glycoside content of the twigs.
[5]These figures include the reducing sugars (stated as dextrose) as well as the glycosidic dextrose; but since the "emulsin hydrolysis" did not involve inversion of sucrose, the figures under this caption comprise the dextrose equivalent of only the original reducing sugars, plus dextrose from the glycoside first hydrolysed; whereas the figures in the last two lines comprise the dextrose equivalent of the total sugars after inversion, plus total glycosidic dextrose.

average difference is not great. This means, of course, that conversely the moisture content is on the whole greater in the tree twigs in February than in December.

There appears to be slightly higher dry matter content and correspondingly lower moisture content in the twigs of trees receiving applications of nitrogenous fertilizers as compared with twigs from unfertilized trees and from trees with no nitrogen, but there is no appreciable decrease in moisture with increasing amount of nitrogen.

TOTAL ASH. It appears to be generally true that the ash content is higher in February than in December. The ash content of the twigs from the fertilizer plots is definitely lower in trend than the ash content of the twigs from unfertilized plots and it would even seem that the complete fertilizers give lower ash figures than the no nitrogen fertilizer.

NITROGEN. The nitrogen content of the twigs for the winter seasons from 1930 to 1933 is higher in February than in December, but for the winter of 1933-34 the nitrogen content is practically the same in both months. The unfertilized plots are definitely lower than the fertilized plots in each winter season. The general trend is for the nitrogen content to increase with increase in nitrogen applied in the fertilizers. The evidence is reasonably conclusive that increasing percentages of nitrogen in the dry matter of the twigs correspond with the increasing amounts of nitrogen applied to the trees; and the divided application of the nitrogen has resulted in higher content as compared with the single application for the 12 per cent nitrogen fertilizers, but is apparently not so definite in the case of the 8 per cent nitrogen fertilizers.

The average nitrogen content of the tree twigs of the 1933-34 winter season is appreciably higher in both December and February than in previous seasons.

The step from the application of 4 per cent nitrogen in the fertilizer to 8 per cent seems to make a more decided increase in the nitrogen content of the twigs than between 8 and 12 per cent.

SUGARS. The sugars in the different years between December and February analyses show no definite trend. The data for the winter season, 1930-31, show February greater than December for reducing sugars and December greater than February for the non-reducing sugars. The data for the winter season 1931-32 show February greater than December for reducing sugars and December greater than February for non-reducing sugars. The data for the winter season 1932-33 show December greater than February for both reducing and non-reducing sugars while for the winter season 1933-34 this relationship is definitely reversed, being higher for both sugars in February than in December. The total sugars are likewise reversed in the two years, being greatest in December in the winter season of 1932-33 and least in the winter season of 1933-34, as compared with the February data for the twigs.

The general trend appears to be that the no-fertilizer and no-nitrogen twigs are higher in reducing sugars than the twigs from nitrogen fertilized trees. In the case of the non-reducing sugars this is not true, although the variations are not wide nor consistent.

There appears to be a general trend toward no-fertilizer and low nitrogen fertilization being associated with the higher total sugar content, although the trend is not very marked.

INFLUENCE OF POTASH. Judging from the results in this limited number of plots, there appears to be no consistent trend discernible due to increase in potash in its effect on any of the constituents determined on the twig samples in this experiment.

GLYCOSIDES. The content of glycosides in the peach tree twigs appears to respond to soil treatments and were highest with the high nitrogen fertilizers and lowest for the trees receiving no nitrogen or no fertilizer. The content of glycosides was higher in December than in the following February.

After hydrolysis the trends are not so apparent; but, nevertheless, the higher dextrose figures are associated with high nitrogen application and the lower dextrose results with the plots on the low nitrogen level. The total dextrose from complete hydrolysis was definitely higher for February than for the preceding December.

NATURE OF THE SUGAR AND THE GLYCOSIDES. Various methods were tried to determine the sources of the dextrose obtained by gentle hydrolysis and also on complete acid hydrolysis. After a review of some recent work on glycosides, it was considered likely that the results of the laboratory work pointed to the glycoside *Prunasin* as the source of the dextrose first obtained; and to either *Phlorhizin* or *Naringin*—or to both—as the source of the remaining dextrose (d-glucose) obtained on hydrolyzing by boiling with 2 per cent hydrochloric acid for 15 minutes.

The presence of phlorhizin is indicated by the formation of a flocculent, reddish precipitate on acid hydrolysis. The aglucone is insoluble in the acid but soluble in alcohol, and exhibits color reactions resembling, but not quite the same as, the aglucone phloretin. On the other hand, the presence of the glycoside *Naringin* is suggested by some of the data obtained. In the work on the glycosidic dextrose, extracts of the peach twigs were first prepared as for the determination of the sugars (in fact, aliquots of the solutions clarified for the sugar determinations were used). In brief, the Prunasin-dextrose was determined on such an aliquot, after digesting with emulsin at 45° to 50° C., in neutral or slightly acid solution. Hydrocyanic acid was eliminated by heating before the *Prunasin* dextrose was determined. The total glycosidic dextrose was then determined on an aliquot of this solution after it had been further hydrolyzed by boiling with 2 per cent hydrochloric acid for 15 minutes.

Repeated trials in the laboratory were made to isolate crystalline sucrose from the peach twig extracts (alcoholic extracts). As much as three liters of composite extract were taken at a time as the starting "charge," but it was only after weeks of laboratory work that a few crystals of sucrose were finally obtained; and identified by their appearance and optical properties by Mr. George L. Keenan, now Microscopist, Food and Drug Administration, Federal Security Agency. Conclusions on one of the principal fractions obtained during one of these laboratory "runs" is as follows:

A fraction was obtained by purifying the alcoholic extract of peach twigs by precipitating the "sugar fraction" with strontium hydroxide, decomposing and removing the strontium, concentrating under vacuum, and precipitating by pouring into absolute alcohol. This sucrose fraction was yellow in color; had a slightly sweetish first taste, becoming very bitter.

Total weight 1.712 g.; moisture 5.6 per cent; ash 14.0 per cent; reducing sugars (as invert sugar) 1.52 per cent; non-reducing sugars (as sucrose) 26.6 per cent; Prunasin 4.07 per cent; remaining glycoside dextrose 8.07 per cent.

1. The data for the optical rotation and copper reduction before and after inversion (by pure invertase) correlate remarkably well, if it be assumed that the original reducing sugars are invert sugar, and the substance hydrolyzed by invertase is sucrose.

2. All of our data support Rabate's[1] findings; namely, that the glucoside Prunasin is the source of the dextrose liberated by emulsin.

3. The optical rotation and copper reduction data before and after hydrolysis by 2 per cent hydrochloric acid (boiling 15 min.), indicate the presence of a strongly laevo-rotary glycoside that is hydrolyzed by the hydrochloric acid to dextro-rotatory sugars. Assuming the glycosides to be *Prunasin* and *Naringin;* the correlated optical rotation and copper reduction data fit surprisingly well.

COLD INJURY. No cold injury occurred during the first two winters, 1929-30 and 1930-31, after the trees were set. In 1930 the minimum temperature[2] for February was 24° Fahrenheit, and for March 24°. In 1931 the minima were 28° in February and 28° in March. The range in temperatures for subsequent years is shown in Table 5, while the cold injury to trees is recorded in Table 6.

During the winter of 1931-32 temperatures were above normal for each month except March, which had a mean temperature 3.8° Fahrenheit below normal and a minimum of 13° Fahrenheit

---

1. Rabate, J. Contribution to the biochemical study of the peach (Persica vulgaris). I. On the presence of amygdo-nitrile glucoside. (trans. title) Bull. Soc. Chim. Biol. 15 (3): 385-394. 1933. See also: Shinoda, J. and S. Uyeda. Uber einen bestandteil baumrinde der pfirsche. (Japanese with German summary) Jour. Pharm. Soc. Japan. 49: 575-578. 1929.
2. Temperatures reported by the official Weather Bureau Station, in Griffin, Georgia, approximately 2 miles from the experimental orchard.

TABLE V

DAILY MAXIMUM AND MINIMUM TEMPERATURE AT GRIFFIN, GEORGIA, FOR WINTER MONTHS 1931 TO 1941

	DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Nov.	Max.	65	63	70	82	80	72	69	70	77	78	80	80	84	83	80	83	78	71	80	79	72	80	81	81	75	64	56	60	68	78	
1931	Min.	31	32	35	42	45	38	33	35	40	45	46	49	49	51	50	52	53	57	61	58	59	55	52	50	51	40	46	45	50	55	
Dec.	Max.	78	54	51	59	64	66	55	50	42	67	71	76	79	73	63	61	52	66	77	68	66	69	73	76	63	64	57	68	70	59	61
1931	Min.	48	40	34	35	31	38	40	36	28	37	45	55	59	63	32	33	38	42	46	58	57	47	46	54	40	31	30	37	36	42	46
Jan.	Max.	60	59	60	56	55	62	61	51	53	55	59	67	77	79	76	69	72	66	61	66	73	74	75	67	65	64	66	70	76	67	56
1932	Min.	39	30	32	30	40	44	47	46	31	23	31	43	59	61	55	56	55	51	31	31	43	50	48	54	30	47	42	38	52	48	22
Feb.	Max.	62	60	78	69	65	63	73	72	63	80	77	74	66	59	54	50	62	67	59	63	56	61	68	60	72	76	75	74	78		
1932	Min.	29	41	57	60	26	36	51	57	49	47	54	55	40	40	39	41	40	41	44	37	39	39	36	36	43	41	46	44	40		.
Mar.	Max.	82	83	81	74	64	53	51	50	43	44	55	53	47	48	49	64	66	68	73	80	74	71	55	73	72	79	73	65	67	69	70
1932	Min.	49	52	59	58	41	25	24	25	24	13	23	28	17	24	20	37	53	38	39	49	57	51	32	33	42	46	47	38	40	47	52
Nov.	Max.	68	67	64	60	66	63	65	71	65	69	62	53	52	53	66	60	52	60	62	59	67	68	58	53	62	58	52	49	54	66	.
1932	Min.	51	37	41	47	49	54	56	57	39	35	43	28	23	29	34	46	28	40	37	27	39	30	31	41	47	52	28	24	23	31	..
Dec.	Max.	68	69	67	60	66	68	69	59	60	59	59	53	58	62	55	43	33	34	46	44	45	56	61	62	71	60	70	67	59	72	68
1932	Min.	34	37	39	45	44	44	45	31	33	42	45	50	45	55	31	29	23	24	29	28	29	38	45	44	59	49	48	59	47	54	55
Jan.	Max.	48	51	63	68	72	69	68	67	60	59	68	69	46	54	60	62	70	73	69	75	69	66	70	71	63	62	55	51	59	52	60
1933	Min.	23	22	36	42	50	37	50	46	43	31	42	38	33	31	30	36	43	47	48	55	54	54	48	42	53	38	44	30	27	38	34
Feb.	Max.	56	71	70	60	46	45	60	55	37	34	35	48	50	69	65	45	52	68	60	61	67	62	65	65	75	69	61	59	...		.
1933	Min.	45	50	44	40	32	19	37	46	6	20	24	20	30	41	53	34	36	47	43	50	33	38	50	47	53	37	34	42	...		....
Mar.	Max.	62	62	67	55	42	59	58	52	68	62	68	75	78	80	77	70	77	83	67	74	71	75	70	65	64	71	75	75	74	76	78
1933	Min.	34	32	24	26	27	32	38	36	37	33	28	37	50	60	52	40	49	58	63	53	33	46	33	44	39	35	45	42	42	48	55
Nov.	Max.	79	76	74	73	70	54	61	57	65	58	67	74	66	65	63	54	60	58	67	74	73	67	64	61	62	61	60	70	74	76	....
1933	Min.	55	56	58	57	45	44	40	32	30	25	30	40	48	30	31	23	26	38	34	30	41	52	41	32	39	25	37	41	42		....
Dec.	Max.	78	71	70	73	76	64	65	66	61	62	71	64	65	72	74	76	79	77	73	64	63	70	73	71	69	70	52	51	56	49	64
1933	Min.	48	45	51	43	46	50	39	33	35	26	43	48	37	50	51	46	53	52	58	42	33	37	43	45	52	51	21	28	31	27	32

Jan. 1934	Max.	66	61	57	45	49	63	69	57	46	53	57	51	62	60	61	66	61	65	55	58	55	66	67	64	56	70	71	67	51	25	41
	Min.	53	35	34	33	36	43	56	37	30	27	27	37	38	29	27	32	27	29	38	41	41	42	46	35	42	46	48	47	17	5	13
Feb. 1934	Max.	50	56	62	74	71	56	61	64	56	32	31	46	65	67	70	67	56	67	53	51	54	53	51	47	72	64	40	36			
	Min.	28	32	32	38	35	26	27	36	34	13	15	28	31	28	40	41	31	25	37	13	25	34	28	27	34	32	12	18			
Mar. 1934	Max.	57	69	68	69	69	75	76	74	54	58	45	55	66	69	61	69	75	78	78	66	76	71	68	56	46	49	66	66	65	67	74
	Min.	26	36	58	56	43	44	49	58	29	34	18	20	30	34	22	35	43	45	44	27	38	47	50	32	31	37	44	51	38	44	47
Nov. 1934	Max.	73	68	64	76	77	68	85	82	78	80	71	54	64	63	61	70	75	79	76	67	74	75	68	67	68	55	56	57	63	73	
	Min.	62	38	48	56	48	42	44	52	46	49	39	29	29	42	34	36	42	48	50	52	62	63	47	35	36	39	45	49	59	61	
Dec. 1934	Max.	55	53	54	55	59	59	58	46	47	39	35	42	59	58	62	65	62	53	54	51	59	58	62	51	65	65	58	52	53	52	45
	Min.	40	33	41	38	32	42	40	23	24	30	18	16	29	29	34	51	42	42	38	27	32	40	34	44	42	47	36	38	44	51	37
Jan. 1935	Max.	50	57	62	60	46	51	59	62	69	70	63	60	70	61	65	68	59	58	52	76	68	38	46	36	46	58	55	60	51	49	
	Min.	35	27	35	34	37	38	50	55	47	46	47	37	45	37	36	48	58	48	45	41	17	23	28	33	22	28	30	26			
Feb. 1935	Max.	45	61	68	53	61	71	64	48	74	66	53	49	49	54	62	66	57	52	64	60	61	72	61	74	68	65	52	44			
	Min.	25	29	37	33	28	40	31	35	45	48	41	43	42	44	52	53	40	32	36	35	31	44	32	40	41	50	**22**	**16**	...	...	...
Mar. 1935	Max.	61	69	75	73	63	71	67	54	53	59	73	67	60	68	73	78	69	63	73	84	85	86	87	82	81	76	72	70	76	80	...
	Min.	28	37	44	48	57	55	54	35	39	38	58	55	30	41	45	46	55	39	47	58	60	56	60	62	59	58	60	43	50	66	
Nov. 1935	Max.	86	85	84	74	70	69	75	72	70	69	78	72	67	72	72	62	63	66	69	65	65	67	51	53	62	70	75	66	60	56	...
	Min.	59	58	57	62	61	59	60	52	51	56	61	64	49	46	50	52	43	35	42	49	34	40	26	23	32	36	42	54	36	29	...
Dec. 1935	Max.	64	44	54	52	58	66	61	56	68	67	54	52	54	49	56	52	51	58	60	53	40	33	53	50	44	39	41	37	34	36	33
	Min.	40	27	23	29	30	33	37	42	50	40	28	33	39	36	41	36	26	31	35	25	11	28	27	26	21	13	14	25	17	26	24
Jan. 1936	Max.	32	42	52	55	56	51	53	52	61	60	64	68	62	64	65	67	72	70	63	42	50	56	46	47	56	51	44	41	35	40	30
	Min.	29	31	41	35	28	41	45	47	39	34	41	35	43	36	46	41	49	53	33	21	24	31	16	**14**	27	38	16	**11**	21	27	**9**
Feb. 1936	Max.	46	40	38	65	41	39	56	42	48	40	35	56	47	64	60	55	63	59	47	60	51	58	66	71	75	75	65	65	70		
	Min.	13	33	32	36	28	34	30	31	31	27	17	26	36	44	36	44	44	26	21	33	37	30	35	41	50	51	49	36	42		
Mar. 1936	Max.	73	72	69	71	70	71	72	74	68	73	76	65	65	63	72	79	64	58	70	57	70	74	70	79	72	87	78	71	74	80	80
	Min.	46	42	50	49	55	42	38	45	49	52	50	42	35	45	47	54	35	31	35	42	35	41	42	51	58	64	61	47	49	53	60

TABLE V—Continued

DAILY MAXIMUM AND MINIMUM TEMPERATURE AT GRIFFIN, GEORGIA, FOR WINTER MONTHS 1931 TO 1941

	DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Nov. 1936	Max.	76	81	83	76	66	55	61	71	74	68	56	54	69	71	62	60	69	73	58	71	71	59	68	57	56	49	45	55	65	56	....
	Min.	50	56	61	45	35	51	49	54	46	44	42	44	49	46	47	80	32	47	43	39	48	33	36	44	42	27	26	22	38	40	....
Dec. 1936	Max.	46	39	49	57	59	72	70	51	47	52	53	52	55	49	45	49	66	67	59	58	59	61	55	59	64	68	69	65	70	65	63
	Min.	31	29	38	38	39	41	47	35	35	41	48	35	30	38	40	41	40	44	46	28	32	38	36	33	38	44	50	55	55	56	59
Jan. 1937	Max.	60	61	59	53	44	48	49	65	74	78	74	72	74	77	67	64	58	75	64	59	62	76	75	76	69	57	54	49	53	51	53
	Min.	50	50	46	35	37	41	42	48	56	54	59	50	54	58	57	39	46	52	53	53	46	58	60	60	56	47	45	34	39	41	45
Feb. 1937	Max.	60	58	54	56	56	67	76	78	70	52	53	61	53	58	66	62	55	66	50	49	64	55	66	62	54	47	40	44	..	.....	...
	Min.	45	30	32	39	29	35	54	60	50	31	**22**	31	42	47	39	38	29	41	38	42	48	30	37	42	36	**21**	32	33	..	..	....
Mar. 1937	Max.	48	60	68	72	71	72	65	62	59	66	72	75	78	65	62	53	62	61	76	78	68	68	78	70	75	67	52	53	56	59	66
	Min.	28	25	36	40	49	42	47	49	35	30	42	48	47	54	35	25	29	45	49	57	44	45	47	57	59	42	40	28	34	45	40
Nov. 1937	Max.	71	78	68	64	65	71	73	75	78	77	66	55	73	69	68	56	51	58	54	52	41	45	44	54	53	56	66	67	61	63	....
	Min.	53	48	46	36	40	39	43	45	54	56	54	43	49	46	40	46	36	27	36	22	19	19	23	29	44	46	52	36	29	35	...
Dec. 1937	Max.	59	55	58	59	52	39	39	50	43	44	45	47	59	66	71	72	69	64	60	68	54	61	51	64	68	66	58	73	62	65	66
	Min.	42	34	32	40	44	19	11	24	27	20	18	22	40	41	39	49	57	51	41	32	39	33	40	43	42	45	48	44	40	38	44
Jan. 1938	Max.	61	58	59	64	63	51	50	44	49	48	47	50	49	50	55	64	60	64	57	48	69	72	70	73	64	43	36	45	59	67	59
	Min.	53	41	33	34	33	42	40	24	25	35	39	38	27	33	32	34	49	48	44	40	45	54	54	58	33	22	**18**	**16**	27	39	47
Feb. 1938	Max.	54	55	71	72	72	71	68	69	75	80	76	76	77	80	74	67	53	78	68	49	63	61	58	53	46	63	69	63	.....	.....	....
	Min.	29	30	41	46	49	55	50	40	45	44	55	45	52	53	50	47	43	45	49	34	33	44	46	34	31	28	35	37	....	..	..
Mar. 1938	Max.	63	71	78	64	77	69	65	68	60	65	67	71	75	76	77	70	61	76	77	79	81	84	78	71	79	81	73	69	82	84	81
	Min.	29	38	53	45	48	55	30	38	49	53	41	40	44	53	62	56	46	41	50	55	50	62	57	52	45	52	53	50	59	57	61
Nov. 1938	Max.	82	81	77	76	82	80	76	71	65	67	70	82	81	74	73	58	79	81	72	66	63	70	71	61	48	50	42	50	59	66	.
	Min.	56	56	50	57	59	62	65	50	32	45	50	54	59	54	40	48	48	61	62	39	39	50	58	40	25	32	26	20	25	35	..
Dec. 1938	Max.	67	65	61	72	65	56	66	59	52	57	68	67	61	61	58	52	53	53	58	63	58	53	63	60	58	61	59	44	40	54	50
	Min.	38	40	38	50	53	35	37	43	40	26	38	48	44	42	34	31	34	40	28	34	43	27	33	48	33	43	42	21	30	33	33

Jan. 1939	Max.	66	68	70	71	66	64	69	71	70	69	64	62	56	55	54	54	51	55	54	63	68	52	46	58	52	57	46	50	51	64	58
	Min.	34	40	44	53	55	36	42	46	46	50	56	48	43	32	33	35	33	45	28	35	39	40	27	42	30	34	28	30	36	48	32
Feb. 1939	Max.	56	62	70	66	55	67	64	63	76	78	70	58	61	76	68	58	67	76	78	71	61	44	46	60	65	69	58	63	..	.	.
	Min.	39	42	60	30	36	50	40	42	55	61	44	35	38	52	52	31	38	47	54	55	40	**22**	**18**	28	36	47	45	53	..		...
Mar. 1939	Max.	55	51	54	66	78	73	69	71	79	74	80	74	69	74	73	63	60	62	60	74	76	81	82	86	81	76	74	79	75	74	68
	Min.	40	40	31	44	55	55	35	47	47	53	52	61	42	46	53	39	30	40	29	37	45	44	50	56	58	59	56	54	53	54	45
Nov. 1939	Max.	69	75	66	63	61	67	61	78	72	76	78	66	66	69	71	73	78	68	60	68	59	58	56	62	52	55	58	69	67	66	.
	Min.	33	41	42	40	33	33	40	44	42	43	54	49	44	44	45	50	50	55	51	54	46	42	31	35	40	37	30	32	38	44	...
Dec. 1939	Max.	59	64	54	57	66	71	76	74	73	73	68	66	60	59	60	67	73	75	66	69	63	62	49	46	55	49	46	48	41	45	51
	Min.	50	48	34	31	35	42	43	43	43	47	48	37	42	27	31	40	49	45	53	39	31	29	42	36	32	41	40	36	30	23	30
Jan. 1940	Max.	40	38	44	48	48	47	40	34	44	49	48	43	48	63	48	55	57	60	48	27	42	48	40	36	27	26	31	39	43	46	51
	Min.	30	16	45	23	32	22	29	30	23	27	35	37	41	43	27	26	30	35	14	**9**	15	17	31	24	15	**6**	5	**9**	19	30	22
Feb. 1940	Max.	58	48	54	42	46	65	57	55	60	69	58	65	68	58	47	52	48	60	52	41	42	42	49	49	50	56	58	70	72	....	.
	Min.	29	31	20	29	36	45	38	28	28	40	31	38	45	31	40	36	37	36	39	35	36	32	25	36	40	23	37	46	41	....	..
Mar. 1940	Max.	72	74	68	63	59	62	63	51	57	68	74	65	50	50	58	73	77	75	75	72	68	67	67	57	52	58	58	68	78	72	79
	Min.	45	51	53	43	39	32	36	39	28	33	45	46	37	36	30	39	46	48	49	42	44	45	37	41	26	30	38	51	58	57	45
Nov. 1940	Max.	72	75	82	78	76	70	71	68	62	59	71	62	55	48	40	48	67	68	68	69	74	78	73	67	63	57	47	53	62	61	...
	Min.	60	47	49	52	56	48	40	36	38	47	57	47	48	36	**21**	**18**	30	33	40	45	54	55	57	60	57	46	42	28	33	38	.
Dec. 1940	Max.	56	56	48	55	62	60	52	63	63	72	71	71	63	73	62	65	45	58	49	54	68	62	60	53	54	55	67	65	57	59	63
	Min.	45	34	33	26	38	32	36	36	34	40	48	53	55	58	42	44	33	31	35	39	41	40	42	41	46	50	53	56	45	35	35
Jan. 1941	Max.	65	61	57	56	46	46	50	53	60	53	57	66	72	65	56	42	60	52	46	58	62	66	69	64	66	56	59	56	55	63	65
	Min.	43	54	42	28	30	26	31	27	30	28	33	26	37	39	37	40	41	40	28	26	32	43	51	50	36	41	43	31	30	31	45
Feb. 1941	Max.	58	56	53	58	62	54	53	44	45	54	58	63	59	55	58	59	59	58	51	49	58	51	57	49	51	47	45	43			.
	Min.	32	40	39	24	30	39	40	23	22	25	31	36	36	42	30	29	45	36	31	34	29	29	25	32	35	35	39	28			...
Mar. 1941	Max.	45	63	69	69	58	61	56	47	59	67	60	63	55	55	57	64	59	46	64	62	57	62	59	70	69	70	63	63	58	68	63
	Min.	21	26	41	57	26	35	43	39	31	35	36	33	39	29	30	42	36	23	30	44	48	50	46	45	43	45	50	37	35	34	42

on March 10. On this date some flowers on the Elberta trees were fully open and considerable killing of flower buds and some cambium injury occurred in the experimental orchard (see Table 6), as well as in commercial orchards throughout the Georgia peach belts. In the experimental orchard injured flower buds ranged from 60 to 74 per cent without consistent relation to the fertilizer treatments; while trunk injury was confined to trees which had received no nitrogen—two in the check (no fertilizer) blocks, 2 in the no nitrogen (0-8-6) blocks, and 4 in guard rows (not fertilized).

The most severe injury of the whole experimental period occurred on February 9, 1933, when, following a period of abnormally warm weather, the temperature dropped to 6° Fahrenheit. At this time Elberta blossom buds were pink. Severe cold injury occurred in flower buds, twigs, and in the cambium of trunks and branches. Injury to buds ranged from 88.9 to 93.9 per cent in the various blocks, again showing no evident relation to fertilizer treatment. Exact counts of twig killing could not be obtained, due to the necessity of pruning before leaves appeared, but it appeared to be worst on the no-fertilizer and the no-nitrogen blocks. Trunk injury was distinctly most severe on these blocks, but some injury was found on three trees receiving the 8-8-6 fertilizer applications, while none was found in the 6 blocks receiving the highest applications of nitrogen.

During January and February, 1934, there were no extended periods of warm weather. The mean temperature for January was slightly above (0.8°) and for February 5.8° below normal, with minima of 13° February 10 and 12° on the 27th. Due to absence of warm periods during these two months, peach buds were only slightly swollen at the end of February and a temperature of 12° killed only an occasional flower bud and caused no trunk injury.

In 1935 a minimum temperature of 16° on February 28 caused slight injury to flower buds and to trunks.

The winter of 1935-36 was unique in several respects. November temperatures approached record extremes but the mean temperature for the month was 3.9° above normal. December was, with the exception of December 1917, the coldest on record, with minimum temperatures of 11° on the 21st and 13° on the 26th and a mean for the month of 6.9° below normal. The most severe ice storm in 30 years started on December 28 and the ice remained on trees until January 2. The ice coating was approximately an inch thick on trees and great damage to forest and shade trees occurred; but properly headed peach trees were not broken and examination immediately after the ice melted showed little damage from cold. Only an occasional flower bud had been killed to this date. The mean temperature for January was 3.3° below normal, due to extended cold period the last two weeks of the month. Temperatures considerably above normal obtained from

TABLE VI

COLD INJURY TO PEACH TREES, NUMBER OF TREES SHOWING TRUNK INJURY, FROM 3 BLOCKS OF 16 TREES EACH, AND AVERAGE PERCENTAGE OF DEAD FLOWER BUDS IN BLOCKS RECEIVING FERTILIZER APPLICATIONS INDICATED.

FERTILIZER FORMULA N-P-K APPLIED	NONE		0-8-6		4-8-6		8-8-6		4-8-6 4-0-0		12-8-6		4-8-6 4-0-0 4-0-0	
COLD INJURED	TRUNKS	FLOWER BUDS	TRUNKS	FLOWER BUDS	TRUNKS	FLOWER BUDS	TRUNKS	FLOWER BUDS	TRUNKS	FLOWER BUDS	TRUNKS	FLOWER BUDS	TRUNKS	FLOWER BUDS
year	*no.*[1]	*per cent*	*no.*	*per cent*	*no.*	*per cent*	*no.*	*per cent*	*no.*	*per cent*	*no.*	*per cent*	*no.*	*per cent*
1932	2	62.5	2	74.0	0	60.0	0	60.0	0	64.0	0	64.0	0	60.0
1933	7	88.9	11	93.2	8	96.2	3	92.6	1	92.6	0	93.9	0	93.4
1934	0		0		0		0		0		0		0	
1935	2	11.9	0	11.6	0	9.9	0	7.0	0	10.7	0	8.8	0	7.4
1936	6	46.0	4	43.0	2	53.0	1	41.0	2	45.0	0	38.0	0	46.0
1937	6	30.9	3	32.3	2	31.5	0	35.4	0	29.4	0	32.1	0	26.5
1938	4		0		1		0		0		0		0	
1939	4	70.1	4	70.0	2	75.0	0	77.2	0	79.8	0	74.1	0	69.3
1940	3		2		9		0		3		0		0	
1941	9		3		3		0		1		1		1	
Total	42		29		27		4		6		1		1	
Percentage injured	87.50	51.7	60.42	54.0	56.25	54.3	8.33	52.2	12.50	51.8	2.08	51.8	2.08	50.4

[1]A few injured trees partially recovered from the injury and were again cold injured in subsequent years and were therefore counted twice.

the 6th to 18th, sufficient to cause some swelling in peach buds. The later cold period culminated in a record snowfall of 5.5 inches on the 29th and 30th and a temperature minimum for the year of 9° on the 31st. Considerable cold injury to flower buds and also to the trees occurred at this time.

The following winter, 1936-37, was abnormally warm. There was no freezing weather during January and peach buds began opening irregularly by the latter part of the month, the irregular blossoming being due to lack of sufficient cold to break the rest period. A hard freeze on February 11 with a minimum temperature of 22° caused considerable injury, as shown by bud counts (Table 6) on the 18th. Another hard freeze on the 26th, minimum 21°, and three light freezes during March, killed nearly all flower buds and young fruits, but exact counts were not made after the late freezes. Cold injury to the trunks occurred with both February freezes.

During October, November, and the first half of December, 1937, temperatures were much below normal, with minima of 19° on November 21 and 11° on December 10. For January 1938 the mean temperature was close to normal with a warm period extending January 16 to 24, sufficient to induce a sappy condition in peach trees, followed by a hard freeze with a minimum of 16° on January 28 which injured a few trees. February and March temperatures were above normal with only light freezes and there was little injury to flower buds.

The winter of 1938-39 was mild. November was unusually warm with no freezing weather until the 24th. December and January temperatures were slightly above normal. February was abnormally warm until the 22nd when there was a sudden drop to 22° and to 18° on the 23rd. At this time peach blossom buds were beginning to open and approximately 75 per cent were killed. Considerable injury to trunks occurred at this time.

The mean temperatures were normal or only slightly below during November and December, 1939, with no hard freezes. This was followed by the coldest January on record for the state as a whole. At Griffin the minimum, 5°, occurred on the 27th. Peach blossom buds were severely damaged. The percentage killed in the Griffin area ranged around 75 per cent for Early Rose and 90 to 98 per cent for Elberta. In our experimental orchard 98 per cent of the blossom buds were killed but only slight injury to trunks occurred. In the southern part of the peach belt from Thomaston south, injury to the crowns and trunks was more severe. In several orchards about Thomaston and Fort Valley the cambium was injured so severely that the bark separated from the wood even on the small branches. Many growers, never having seen this type of injury before, assumed that such trees were killed and allowed many trees to be stripped of bark. Nearly all trees from which the bark was not stripped recovered and grew off normally the following spring. However, some trees in low

spots were killed or severely injured at the crown. In northern Georgia, where the temperature dropped to from —5° to —17° Fahrenheit, some injury to the roots was reported. This type of injury appears to be rather rare in Georgia.

The mean temperature for November 1940 was about normal; but the range was unusually wide with a maximum of 82° on the third and a minimum of 18° on the morning of the 16th. This is the lowest temperature ever recorded here so early in the season. Previous to this latter date, no frost had occurred and many peach trees were still in full leaf and apparently had high moisture content. The sudden freeze caused considerable injury to the trunks in the experimental orchard and also in many commercial orchards throughout the state. Reference to Table 6 shows that the damage was most severe in the unfertilized blocks, but some trees were injured in the blocks receiving the highest rates of nitrogen fertilization. Flower buds were not injured at this time nor by any subsequent freezes. The November 16 temperature was the lowest occurring during the entire winter. While the mean temperatures for February and also for March were below normal, this was due to absence of the usual warm periods rather than to periods of abnormally low temperatures. Consequently, peach trees came into bloom extremely late and no bud or flower injury was recorded.

RELATION OF SUNLIGHT TO COLD INJURY. The trees of border rows, 38 of which were painted with whitewash and 38 with a blackwash, received no fertilizer and appeared very uniform when the test was started. However, by the end of the 1934 growing season the roots from the border trees had apparently spread into the fertilized areas of adjoining blocks and showed irregularity of growth. Consequently the applications were not continued after the winter of 1933-34.

The number of trees showing cambium injuries under these white and black surfaces during the three years were as follows:

	Under whitewash	*Under blackwash*
1931-32	3	1
1932-33	1	1
1933-34	0	0

DISCUSSION

Several workers have discussed the hypothesis that absorption of radiant heat by bark on the south and southwest side of tree trunks is related to the occurrence of the "sunscald" type of cold injury. It seemed therefore that a pure white paint, reflecting a high percentage of this radiant energy might afford considerable protection from cold injury.

While the number of trees used in this test was too low to justify general conclusions, the results do indicate that whitewash-

ing the tree trunks as occasionally practiced by orchardists is probably of little value in this region.

The most striking result obtained from this study is the effect of nitrogen applications in reducing susceptibility of peach trees to cold injury and the total lack of correlation between nitrogen fertilization and cold killing of flower buds under Georgia conditions. Examination of the total number of cold injured trees as reported in Table 6 shows a sharp drop in cold injury in passing from the blocks receiving 4 per cent to those receiving 8 per cent nitrogen in the fertilizer while further increase to 12 per cent apparently increased resistance to some extent. The figures in Table 6 do not give a complete picture of the comparative susceptibility of trees in the various blocks. They show only the number of trees injured without regard to the extent of the injury, which might vary from a small pocket in the crotch or narrow streak on one side of the trunk to complete girdling and death of the tree. Generally a decrease in severity of injury with increase of nitrogen fertilization was evident and much fewer of the injured trees died on the high nitrogen plots. At present the trees remaining alive on the no-fertilizer and on the 0-8-6 plots are in very poor condition—many are mere stubs with one or two small living branches.

During the first 9 years of the study no cold injury was found on any tree in the blocks receiving 12 per cent nitrogen applications but in 1941, 2 trees in these blocks showed injury on the trunks. Undoubtedly, the roots of trees on the outer border of each block have spread into adjoining blocks tending to equalize nutrients obtained by these trees, and some of the trees in the high nitrogen blocks have doubtless been robbed of a part of the fertilizer applied. This has become quite evident from comparison of border trees adjoining the various blocks. Furthermore, the trees are now too crowded on the high nitrogen blocks for continued healthy growth. For a long-time study, such as this, the trees should have been spaced at least 25 feet within each block and 30 feet between blocks instead of the uniform 17½-foot spacing used in this test.

During the first few years of the experiment there was no apparent difference between the trees of the unfertilized blocks and those receiving phosphate and potash (no nitrogen) either in the generally observed growth and vigor of the trees or in susceptibility to cold injury, but in later years the trees receiving phosphorus and potash did appear to have some advantages with regard to cold injury. Evidently a deficiency of any nutrient weakens a peach tree and causes greater susceptibility to cold injury, but soils that have received heavy applications of phosphorus and potash to previous crops may have sufficient reserves of these two elements to sustain healthy growth of peach trees over a short period of years. In our soil, nitrogen deficiency was the first and most important deficiency as evidenced by vigor and by susceptibility to cold injury.

The series on which a summer cover crop was grown during the first five years showed less difference in growth and vigor of the trees, in response to variations of fertilizer applications, than the other two series. Probably the nitrogen supplied by the heavy seeding of soybeans was sufficient to produce increased vigor in young trees. After the cover crop was discontinued, the check block and no-nitrogen block trees deteriorated rapidly. However, there was no late twig growth in any trees in the orchard. It would seem that under our conditions this factor need not be considered in regard to cover crops for a peach orchard.

In planning the present work, it was hoped that analytical studies in conjunction with records of cold injury to the trees and temperature records might throw some light upon resistance and susceptibility to freezing injury in plants. However, there is little positive correlation between the chemical data and cold injury to the trees. The greatest amount of cold injury was found in the unfertilized blocks, followed closely by the no-nitrogen blocks. The chemical analyses show that twigs from these blocks were consistently lower in total nitrogen and generally higher in ash and total sugar than twigs from blocks receiving applications of nitrogen. However, the differences were not very large, probably not sufficient to make any material differences in the osmotic values or the freezing points of the cell saps. In this connection, it should be noted that the trees showing the higher ash and carbohydrate content were significantly more susceptible to cold injury. The higher nitrogen content of twigs from the blocks receiving liberal applications of nitrogenous fertilizer is probably significantly associated with greater resistance to cold injury. This relation may be through either increased quantities of protoplasm and smaller vacuoles in cells of the cambial region or the characteristics of the proteins present. Probably both factors affect the ability of the protoplasts to recover from the effect of freezing.

In explaining the total lack of correlation between fertilizer treatment and cold killing of flower buds the two factors that would appear of greatest importance are: 1. At the time bud killing occurred, growth activity was much greater in buds than in the cambial region of the tree and all buds were very sensitive to cold. 2. Through selective deposition of nitrogenous materials first in the growing points and fruiting structures of plants the chemical composition of flower buds in all blocks was probably fairly constant.

Neither the chemical analysis nor the observed development of blossoms indicate any effect of fertilizers in either stimulating or retarding breaking of the rest period in peach trees. Neither was there any evident relation between fertilizer treatment and the onset of dormancy, except the earlier leaf fall from trees of the no-fertilizer and no-nitrogen blocks in years above the normal of sunny days during the fall months. There is, of course, the possibility that this early leaf fall may have been due to water

relations; but the fact that the chemical analysis shows higher carbohydrate content in twigs from these blocks indicates that it was probably brought about by saturation with carbohydrates when nitrogen was inadequate to support further twig growth.

The data in Table 6 show that cold injury was slightly less severe in Block 2, which received phosphorus and potash but no nitrogen, than in Block 1, receiving no fertilizer, which appears to indicate that either phosphorus or potassium or both may influence resistance. This is not surprising, since a review of published results of numerous studies of the influence of various fertilizer elements on resistance of plants, especially wheat and other small grains, indicate that a deficiency of any essential element may cause increased sensitivity to cold. The results of various workers appear conflicting, as when one worker obtains significant increases in cold resistance by applying potash while another obtains no benefit from its use; but such conflicting results are readily understood if we consider that the first worker probably had a deficiency of potassium in relation to other nutrients in his soil while the other had an abundance of this element. It seems probable that a deficiency of any of the essential minor elements might cause increased sensitivity to cold through change in the quantity or the character, or both, of proteids formed in the plant.

In the 3 blocks of 12 trees each receiving increased applications of potash (4-8-10, 4-8-14, and 4-8-18 respectively), there was no evident effect of potash either in relation to cold injury or in the chemical constituents determined in the twigs, when compared with the blocks receiving the basal 4-8-6 fertilizer applications. Apparently, nitrogen was the limiting factor for growth in all cases. Soils of the Cecil series are usually comparatively high in available and in total potash and six per cent potash in the basal fertilizer was evidently more than ample for healthy growth in relation to the nitrogen and phosphorus.

Published results of numerous studies indicate that nitrogen is the plant food most generally deficient in Georgia soils, especially in soils of the Cecil series.

CONCLUSIONS

1. Nitrogen fertilization sufficiently high to maintain vigorous growth of peach trees seemed to increase their resistance to cold injury but did not affect cold damage to flower buds, flowers, or young fruits.

2. The most significant difference shown by chemical analysis of new twig growth from trees receiving different rates of nitrogenous fertilizers was higher nitrogen and slightly lower sugar percentage in twigs receiving higher applications.

3. Comparing the various fertilizer increments, the most significant increase of nitrogen in the twigs and the most significant increase in resistance to cold injury was found in the increase

from four per cent to eight per cent nitrogen, indicating that in this latter proportion nitrogen was closely approaching a balance with other nutrients for normal growth of peach trees.

4. Whether all the nitrogen was applied in early spring or in split applications throughout the growing season made no significant difference under prevailing conditions, either in chemical composition of twigs or resistance to cold injury.

5. There was no evident effect of either fertilizer treatments or cover crops on either the onset or the breaking of dormancy, except that in some years the trees on the no-fertilizer and no-nitrogen blocks dropped their leaves earliest, probably indicating earlier saturation with carbohydrates.

6. During the latter years of the study, trees of the check or no-fertilizer blocks, showed significantly greater susceptibility to cold injury than the blocks receiving phosphate and potash but no nitrogen, indicating the probability that a deficiency of any element necessary for healthy growth of the trees may cause increased susceptibility to cold damage. Therefore, similar results from high nitrogen fertilization may not be obtained on soils that are seriously deficient in other nutrient elements.

7. The results suggest the hypothesis that increased resistance to cold injury in trees of the high nitrogen blocks was due to either greater amounts of proteins and smaller vacuoles, in cells of the cambial region, or to characteristics of these proteins, or to both.